# Lewis River Case Study Final Report

A decision-support tool for assessing watershed-scale habitat recovery strategies for ESA-listed salmonids

## Appendix G: Bankfull Width Model

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# Introduction

Many of the models in the Lewis River Case Study DSS required an estimate of stream width for all reaches within the study area, to allow predictions of habitat parameters and thresholds models. Bankfull width (BFW) measurements were necessary for defining riparian habitat thresholds (Appendix H), fish habitat thresholds and suitability (Appendix I, Appendix J), and calculating spawner capacity (Appendix I). In addition to the DSS, BFW measurements were also used for a study designed to assess the accuracy and precision of BFW field estimates. The specific sampling methods for this study were used for both applications, and are described in this appendix.

We developed a predictive bankfull width model for the Lewis (applicable to similar watersheds) from field BFW measurements provided by the U.S. Forest Service, U.S. Fish and Wildlife Service and Pacific Watershed Institute (PWI). In addition to these, 282 BFW measurements were calculated from ortho photos by the Pacific Watershed Institute, and limited field measurements were collected by the LRCS group in the summer of 2003 (n = 44). We applied the final models to all stream reaches, and used the predicted BFW values to calculate some of the final DSS results.

# LRCS Field sampling

Field sampling by LRCS members (N=88) was conducted near several bridge crossings over both the East Fork and the North Fork of the Lewis River (5 of 11 bridges). In addition, an inventory was taken of all tributaries to the Lewis River that empty directly into the mainstem (i.e., other tributaries and branches were not included). The inventory excluded first order streams, as shown on 1:24,000 topographical maps published by the U.S. Geological Survey and did not include intermittent streams in the determination of stream order. BFW measurements were taken both upstream and downstream of 3 bridges over the Lewis River, and in one direction (chosen randomly) from the two other Lewis River bridges and from all tributary crossings where the stream bed was reasonably accessible. The protocol was to go between 180 and 220 meters up or down from the Lewis River Bridge or 80-120 meters from the tributary crossing. This distance was chosen randomly. BFW measurements were taken at this location with a laser range finder, and at 5 meters above and below this point. Two observers were present on most surveys, and both took the measurements independently. Subsequent to these measurements, the survey crew moved to the adjacent habitat unit (either pool to riffle or vice versa). The direction was randomly selected, as was the location for the center sampling location. Measurements were then taken 5 meters above and below the second center point. The average of all measurements in both habitat units was used to fit the model.

Geographic locations of each site were recorded in Universal Transverse Mercator (UTM) coordinates using a hand-held GPS. The GPS accuracy is less than 15 meters[1] and the DGPS (WAAS) accuracy is 3-5 meters. The DGPS was used whenever possible. For sites where we were unable to obtain a GPS fix, the site description was recorded

[1] Subject to accuracy degradation to 100 meters 2DRMS under the U.S. DOD-imposed Selective Availability Program.

with respect to nearby landmarks, and the laser rangefinder was used to obtain an estimate of distance from the landmark. Digital 1:24,000 topographic quadrangle maps were used to manually locate and create GIS points for missing site data, and these were joined with the GPS-derived site locations. Field data were linked to the spatial data. All site locations were snapped to the base stream coverage (WDFW-SSHIAP 1:24,000 streams), and spatial and non-spatial stream attributes were linked to the BFW data. In addition, a spatial join was performed, linking field sites to NetStream, a modeled stream coverage containing additional stream attributes of interest.

## Calibration BFW Data

The three sources of calibration data required some manipulation and analyses in order to maintain consistency between data sources. Details for each source are as follows:

- **Mainstem Measurements (PWI).** Bankfull width field data (N=28) from PWI was available for the mainstem channel of the upper East Fork River above Sunset Falls and Green Fork River and was joined to both the SSHIAP-WDFW and NetStream spatial data. Data were collected by PWI using tapes. Three to seven bankfull widths were taken in each geomorphically-defined reach and averaged (PWI 1998).
- **Aquatic Habitat Survey data (USFS, USFWS).** Multi-year tabular aquatic habitat survey unit-level stream data (N = 481) were obtained from Gifford Pinchot National Forest (GPNF) and the U.S. Fish and Wildlife Service (one stream) (USFS 1995; USFWS 2000). Tabular data were converted to GIS by calibrating survey reaches and unit measurements, and dynamically segmented onto the GPNF or the WDFW-SSHIAP 1:24,000 routed stream coverage, depending on the survey source (ESRI 2004; USFS 2003; WDFW 2000). Width sites were converted to points, and joined to both WDFW-SSHIAP and NetStream stream habitat variables using methods described above.
- **Determining width remotely (PWI).** Bank full width measurements were manually extracted from 1:12,000 digital ortho-photographs (N=282). Bankfull channel edge was defined as the active channel with vegetation type and age used to delineate the boundaries. On-screen digitizing was used to measure channel features and to record site locations. Channel type and vegetation density was recorded to provide an uncertainty metric on channel visibility. Previous work indicates that photo measurements tend to underestimate bankfull width by an average of 5.9 meters (Beechie et al 2005), so orthophoto measurements were adjusted by this amount.

## Geographic variability

The eruption of Mt. St. Helens in 1980 impacted a portion of the North Fork Lewis River watershed, particularly the area around Muddy, Pine and Smith Rivers. The large debris flows following the eruption resulted in BFWs that are larger than they would have been prior to the eruption and thus could not be modeled with the same relationship used to model the non-impacted streams. The volcano impacted reaches were identified from aerial photos and a separate model was generated for these areas.

## Model details

The upstream watershed area for each stream segment was calculated by Dan Miller, and cumulated mean annual precipitation (mm) and reach gradient parameters were available from an earlier version of a Netstream stream network (Miller 2004). These three variables were used as potential predictors. If the positional distance between the BFW measurement location and the nearest NetStream reach was greater than 100 m (n= 2789; 8% of reaches), the NetStream data was considered unrepresentative of the BFW site location. At these sites, NetStream variables were not used, and only drainage area was used to model bankfull width.

Prior to fitting the models, the distribution of the data was assessed. The BFW data were extremely skewed, so a log transformation was used. A normal probability plot indicates some departures from normality, though these are not serious. Each of the predictor variables was also transformed to the log scale to increase the linearity between the predictor and the response.

A series of models was fit to the log BFW data that included all combinations of the three predictors, and all interactions among them. Plots revealed that the relationship between drainage area and BFW was curvilinear, even on the log-log scale, so a quadratic term was included in the candidate set of models as well. The model fit was evaluated by comparing AICs, the model with the smallest AIC was selected for making the basin-wide predictions.

A separate BFW model was needed for volcano-affected reaches in the watershed. For the volcano-affected reaches, the smallest drainage area in the calibration data set was 0.392 $km^2$, and 25.5% of the predictions were for reaches with drainage areas less than this area. However, the problem with increasing BFW predictions in small watersheds was not present, presumably because there was no interaction between drainage area and either precipitation or gradient.

Another model that only had drainage area and the square of drainage area was also fit to the data. This model decreases to the lower limit of drainage area. A graph of model predictions from the two models revealed that the predictions from both were nearly equal when drainage area was about 1 $km^2$, regardless of precipitation or gradient, thus this was a good transition point from the full model to the drainage area only model. This model was also used for stream reaches that did not have precipitation and gradient estimates.

## Model Results and Explanation

The models were subsequently used to predict mean bankfull width throughout the Lewis River basin. An evaluation of the predictions revealed several problem areas. In both of the models, drainage area was clearly the most influential predictor.

The model for the non-volcano affected reaches was a quadratic function of drainage area, and while the model does a good job of predicting BFW for reaches within the range of values used for calibrating the model, the predictions for reaches with drainage areas less than 1 $km^2$ show a tendency to increase with drainage area for most reaches. This arises because of the 751 observations used to calibrate the model for non-volcano affected reaches, the smallest drainage area was 0.293 $km^2$, while 46% of the stream reaches in the Lewis River watershed had drainage areas less than this value. Many of the model predictions in stream reaches with drainage areas less than 1 $km^2$ were very large, particularly in areas of low precipitation and steep channel gradients.

The difference in predictions across the range of gradient and precipitation decreased substantially with increasing drainage area, the differences were only moderate for reaches with drainage areas greater than 1 $km^2$. The large predictions in small watersheds likely arose because of the interaction terms in the model and the fact that there were no observations to calibrate the model in small watersheds.

A second problem was a tendency for BFW predictions to sometimes change dramatically from one reach to the next. This latter behavior was determined to be largely due to changes in channel gradient between adjacent reaches. These changes were amplified by the interaction terms involving gradient. Gradient was removed from the model and the predictions compared to those from the model with gradient. The AIC from the reduced model was 906.1 while that from the full model was 874.1, indicating that the reduced model is likely not the best model for generating the observations (Burnham & Anderson 1998). However, the root mean squared prediction error (RMSPE) for the reduced model was slightly lower than that for the full model (4.10 vs. 4.00) suggesting that the reduced model described mean BFW as well as the larger model, at least in the reaches with observations. Gradient was removed from all models and the models were recalibrated. A reexamination of the predictions from the two models from non-volcano affected areas indicated that the drainage area where the predictions coincided had shifted upward, to 1.43 $km^2$, so that value was used as the transition point.

There were approximately 500 reaches that did not have drainage area estimates. If the reach was at the upstream terminus of the stream (indicated by an increase in the drainage area of the next segment), then the reach was given the same BFW as the adjacent reach. If the reach was between two reaches, then the logBFW from the two adjacent reaches was averaged and back-transformed. Figure G-1 shows predictions from the three models.

For the stream reaches not impacted by Mt. St. Helens, the model for drainage areas larger than 1.43 $km^2$ was:

$$\log(BFW) = 3.43 - 5.20 \log DA + 0.94 \log DA^2 - 0.23 \log Precip$$

(1.77) (1.23) (0.20) (0.23)

$$+ 0.68 \log DA * \log Precip - 0.12 \log DA^2 * \log Precip$$

(0.16) (0.025)

For the non-volcano impacted reaches with drainage areas smaller than 1.43 $km^2$ and reaches without reliable precipitation estimates the model used was:

$$\log(BFW) = 1.65 + 0.28 \log DA + 0.018 \log DA^2$$

(0.062) (0.035) (0.0046)

For the volcano impacted reaches, the model used for all reaches was:

$$\log(BFW) = 12.30 + 0.22 \log DA - 1.20 \log Precip$$

(6.03) (0.049) (0.76)

where:

log(BFW) is the natural log of bankfull width in meters

logDA is the natural logarithm of watershed area above the reach in $km^2$

logPrecip is the natural log of the cumulative annual precipitation in mm

Standard errors of parameter estimates are shown in parentheses

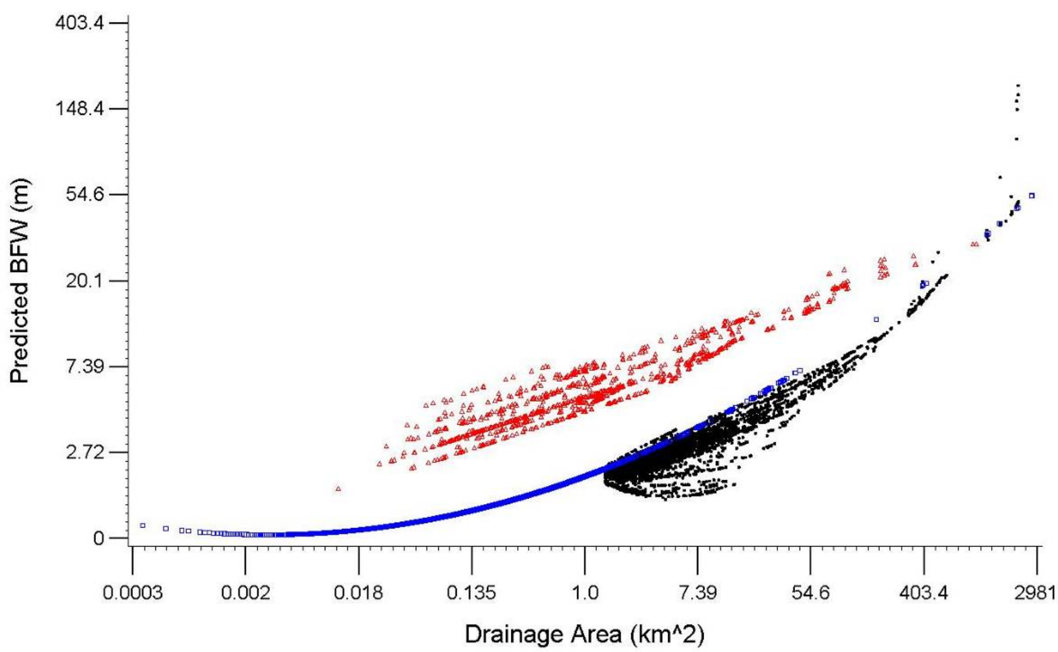


**Figure G-1: Predicted BFW vs. drainage area from each of the three models used in the Lewis River basin. Blue squares are predictions from non-volcano affected areas with drainage area < 1.43 $km^2$, black dots are predictions from non-volcano affected areas with drainage area > 1.43 $km^2$ and red triangles are predictions from volcano affected areas. Note: scales on both axes are logarithmic.**

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